# EXECUTIVE SUMMARY

## DCERP Annual Technical Report III:
## March 2009–February 2010
## Executive Summary

## SERDP Project RC-1413

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# DCERP Annual Technical Report III: March 2009–February 2010 Executive Summary

## Overview

The Defense Coastal/Estuarine Research Program (DCERP) is a research-based program sited at Marine Corps Base Camp Lejeune (MCBCL) in North Carolina. This program provides a unique opportunity to integrate the results of broadly scoped, interdisciplinary ecological research to understand the structure and function of diverse and complex coastal ecosystems, while synthesizing research results to address the MCBCL's management needs for sustaining the military training mission. DCERP is an adaptive program where monitoring data from research models and research discoveries can be used to adapt the temporal and spatial aspects of monitoring activities to efficiently fill data needs and advance the understanding of the coastal ecosystems. Phase I of DCERP was successfully completed in June 2007 and resulted in the development of the *DCERP Strategic Plan*, the *DCERP Baseline Monitoring Plan*, and the *DCERP Research Plan*, which serve as the foundation for DCERP activities at MCBCL. Implementation of these plans (Phase II) began in July 2007 and resulted in the establishment of more than 300 monitoring and research sites and 13 research projects. In addition, the Data Information and Management System (DIMS) was developed and currently archives DCERP monitoring and research data and provides a standard data format that optimizes data storage and retrieval for integrated analysis, allowing for exchange of information among the various DCERP partners. Research and monitoring activities during Phase II of DCERP are currently planned for 4 years (until November 2011) in support of the minimum 10-year vision for the program. This Executive Summary highlights the Phase II accomplishments inclusive of March 2009–February 2010.

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### Major Highlights and Accomplishments from DCERP in 2009
#### Key findings/outcomes to date with implications for MCBCL management

- A bathymetry survey of the New River Estuary (NRE) provided pivotal data needed to improve the accuracy of cross-cutting predictive models developed by the Aquatic/Estuarine and Coastal Wetlands modules. These data also will provide Base managers with detailed information on underwater hazards (i.e., sandbars) to optimize military training maneuvers in the estuary.
- Preliminary estimates suggest the predominant source of nitrogen loading (>75%) to the NRE comes from areas of agricultural and urban development in the watershed upstream of MCBCL. Lower nutrient loadings to the NRE were estimated from the tributary creeks on Base (<25%), with relatively small loadings (<1%) estimated from groundwater passing though marshes to the estuary. Loading estimates may vary considerably depending on inter-annual hydrologic (storm versus drought years) variability.
- A series of inundation scenarios on MCBCL assets were created combining water levels (from the Sea, Lake and Overland Surges from Hurricanes [SLOSH] model and Wave Exposure Model [WEMo]) and wind fields associated with different hurricane landfall simulations. MCBCL emergency preparedness staff used these simulation scenarios during a July 2009 training drill.

#### Program products transferred for immediate MCBCL use

- The entire NRE shoreline was digitized using historic and current aerial photography (1956–2004) to provide accurate geographic information systems data layers for MCBCL use. In addition, the entire shoreline was categorized into five distinct habitat types (including areas modified by hardened structures), and erosion rates were calculated for all estuarine shoreline areas. Information on areas with high erosion rates can inform Base managers of shoreline locations with the greatest vulnerability to damage so that appropriate management actions can be taken to protect existing infrastructure and better plan for future development.
- Thirty years of MCBCL hard-copy files of historic sea turtle nesting data were digitized by DCERP researchers. Analysis of results confirm the effectiveness of MCBCL Endangered Species Act management activities to move nests from military training areas to non-training areas because relocated nests have an average estimated survival rate comparable to or higher than those of undisturbed nests laid in non-training areas.

#### Key DCERP accomplishments at the programmatic level

- Coastal Barrier Module Research Projects CB-1 and CB-2 and the field component of Atmospheric Module Research Project Air-1 began in 2009. Thus, all planned research projects are underway.
- Researchers identified six areas where additional data or tools were needed to provide a clear understanding of ecosystem processes (i.e., NRE bathymetry). The Strategic Environmental Research and Development Program (SERDP) provided supplemental funding to fill these programmatic needs.
- The Monitoring and Research Data and Information System (MARDIS) now contains more than 15-million records of monitoring and research data and spatial data sets. Upgrades to MARDIS improved the system's performance. These upgrades include implementing data access protocols, downloading large datasets, and creating a tool that allows users to display summary statistics (mean, maximum, and minimum values) of selected data sets.

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## ES-1.  Background

Critical military training and testing on lands along the nation's coastal and estuarine shorelines are increasingly placed at risk because of development pressures in surrounding areas, impairments due to other anthropogenic disturbances, and increased requirements for compliance with state and federal environmental regulations. The U.S. Department of Defense (DoD) has mandated that DoD facilities enhance and sustain their training and testing assets and optimize their stewardship of natural resources through the development and application of an ecosystem-based management approach on all DoD lands.

To assist in this goal, SERDP launched DCERP at MCBCL in North Carolina. MCBCL provides an ideal platform for DCERP because it integrates aquatic/estuarine, coastal wetlands, coastal barrier, and terrestrial ecosystems. DCERP is a collaborative effort among SERDP, the Naval Facilities Engineering Command/Engineering Service Center, MCBCL, and the RTI International[1] (RTI) DCERP Team.

> **RTI DCERP Team**
>
> RTI has assembled a diverse team of experts from the following organizations, collectively referred to as the RTI DCERP Team:
>
> - Atmospheric Research and Analysis, Inc.
> - Duke University
> - National Oceanic and Atmospheric Administration
> - North Carolina State University
> - Porter Scientific, Inc.
> - RTI International
> - University of Connecticut
> - University of North Carolina at Chapel Hill
> - University of South Carolina
> - U.S. Army Corps of Engineers
> - U.S. Geological Survey
> - Virginia Institute of Marine Science
> - Virginia Polytechnic Institute and State University

## ES-2.  Integration with MCBCL's Natural Resources Management

As a military installation, MCBCL has needs, or drivers, that must be satisfied to meet its readiness mission without significant disruption. These installation-specific drivers are defined by the Base's mission and geographic location, land uses to support the mission, and natural resources affected by and needed to support the mission (**Table ES-1**). MCBCL must also comply with relevant environmental laws, regulations, and guidelines, such as the federal Endangered Species Act (ESA), the Clean Water Act (CWA), and the Clean Air Act (CAA), to ensure continuance of its mission. To ensure such compliance, in 2007, MCBCL developed and adopted an *Integrated Natural Resources Management Plan* (INRMP). One goal of the INRMP is to minimize future training restrictions (i.e., no net loss in the ability to train) by increasing the integration between MCBCL natural resources management planning and military training and operations. One of DCERP's objectives is to assist MCBCL in achieving this goal by providing science-based understanding and tools to assist management. Base staff were involved throughout the DCERP planning phase and participated in all planning workshops and reviewing the *DCERP Strategic Plan*, *DCERP Baseline Monitoring Plan*, and *DCERP Research Plan*. A DCERP On-site Coordinator serves as a liaison between the Base, the RTI DCERP Team, and SERDP and coordinates and facilitates access to MCBCL lands, facilities, and database files by the RTI DCERP Team.

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[1] RTI International is a trade name of Research Triangle Institute.

**Table ES-1. MCBCL-Specific Military Drivers**

| Driver 1 | Preserving the integrity of the amphibious maneuver areas, including Onslow Bay, the New River Estuary (NRE), and the adjoining training areas and airspace of the Marine Corps Base Camp Lejeune (MCBCL) |
|---|---|
| Driver 2 | Preserving the integrity of MCBCL as a combined-arms training Base by ensuring the continued viability of its impact areas and associated training ranges |
| Driver 3 | Enhancing future training uses of MCBCL ranges, training areas, and airspace by fully integrating the Land Use Master Plan and Range Transformation Plan |
| Driver 4 | Ensuring that MCBCL supports all required military training activities, while complying with the Endangered Species Act (ESA) and other wildlife requirements |
| Driver 5 | Ensuring that MCBCL supports continued military training use of the New River, the NRE, and Onslow Bay, while complying with the Clean Water Act |
| Driver 6 | Ensuring the viability of the U.S. Marine Corps New River Air Station as an aviation facility through the elimination of bird and wildlife strike hazards to aircraft, while complying with the ESA and other wildlife regulatory requirements |
| Driver 7 | Ensuring the viability of MCBCL military training activities, while supporting mission critical infrastructure development |

## ES-3. Summary of the DCERP Baseline Monitoring and Research Activities

To facilitate an understanding of the ecosystem's state and dynamics at MCBCL, the following five ecosystem modules were established for monitoring, research, and modeling: the Aquatic/Estuarine Module, the Coastal Wetlands Module, the Coastal Barrier Module, the Terrestrial Module, and the Atmospheric Module. The DCERP baseline monitoring and research programs were designed to gather environmental data and support research projects aimed at addressing MCBCL's ongoing management concerns. Module-specific monitoring and research sites established during Phase II are shown on a map of the Base (**Figure ES-1**).
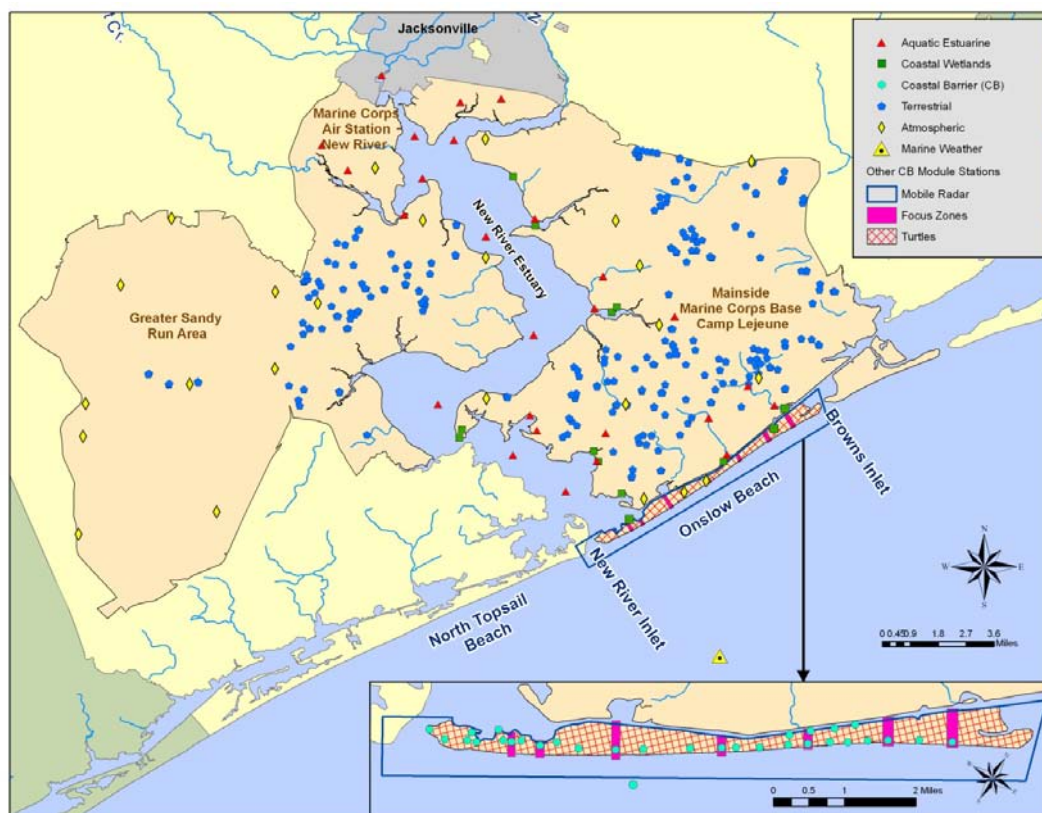


**Figure ES-1. Module-specific monitoring and research site locations.**

DCERP was also designed to be a flexible ecosystem-based research program that is capable of adapting as additional information is analyzed from both the baseline monitoring program and within the individual research efforts. When data needs are identified, the DCERP researchers try to fill the data gaps so that the program as a whole can advance understanding of ecosystem processes. One of the major DCERP objectives is to integrate and synthesize the diverse data collected within the five ecosystems to identify linkages in the basic structure, composition, and function of the environmental system under review. Thus, DCERP adjusts to new information obtained from the monitoring and research programs and from interactions with the Base on critical management issues that need resolution to sustain the military training mission. In addition, DCERP assesses the effects of implementation of management changes through feedback on both the monitoring and research efforts and the ecosystem conceptual models, which are then refined as appropriate (**Figure ES-2**).
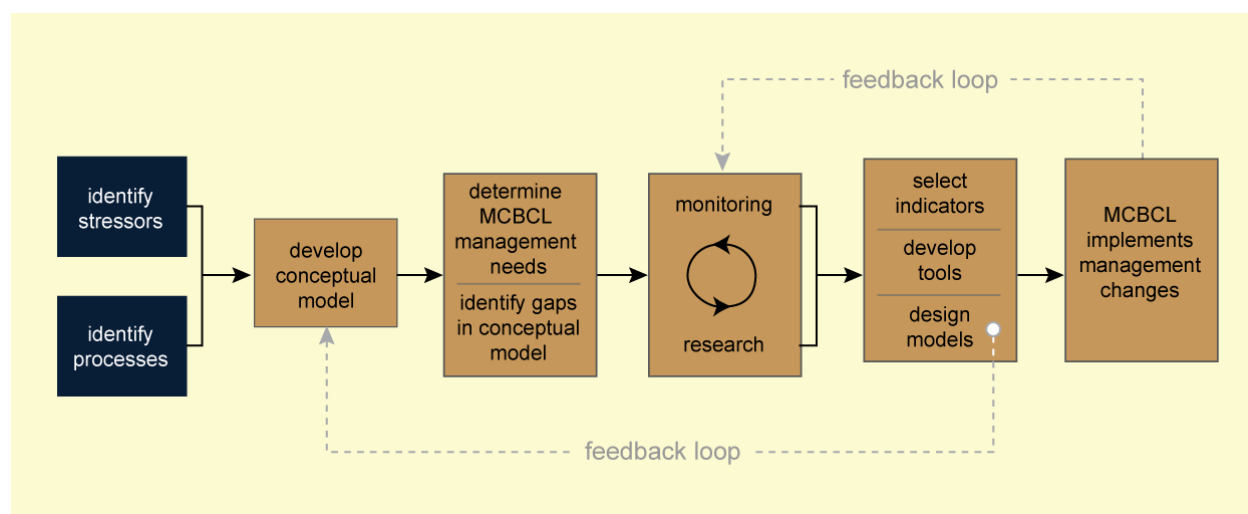


**Figure ES-2. The overall DCERP approach to ecosystem-based management with adaptive feedback loops.**

## ES-3.1   DCERP Baseline Monitoring Program

For the purposes of DCERP, baseline monitoring includes monitoring of basic (fundamental) parameters that support the broader research agendas. The DCERP baseline monitoring program will be implemented for a sufficient period of time to determine the information value of each monitoring parameter. At the end of the DCERP, a cost-effective, scaled-down monitoring program will be transitioned to MCBCL so that Base staff can continue to monitor the health of the ecosystems. The DCERP monitoring program is described in the DCERP Baseline Monitoring Plan and includes the activities listed in **Table ES-2**. All monitoring sites for the five ecosystem modules collected monitoring data during 2009.

**Table ES-2. Summary of Module-Specific DCERP Baseline Monitoring Program Activities**

| Modules | Activities |
|---|---|
| Aquatic/ Estuarine[a] | Hydrodynamics: Stream flow and discharge (New River, NRE, and creeks) <br> Physical/chemical: Temperature, light, salinity, pH, oxygen, nutrients, (New River, NRE, creeks) <br> Sediment-water column interactions: Total suspended solids (TSS) and sediment oxygen dynamics (New River, creeks), turbidity (NRE) <br> Biology: Primary productivity, phytoplankton, chlorophyll fluorescence (NRE) |

| Modules | Activities |
|---|---|
| Coastal Wetlands | <u>Land cover and shoreline erosion</u>: Location, elevation<br><u>Hydrodynamics</u>: Tide gauges (hydroperiod)<br><u>Chemistry</u>: Nutrients, salinity, hydraulic conductivity (shallow groundwater)<br><u>Sedimentology</u>: Accretion rates, organic content, particle size |
| Coastal Barrier | <u>Hydrodynamics</u>: Wave velocity, wave heights/period, currents, shoreline position, morphology<br><u>Meteorology (ocean)</u>: Air temperature, wind velocity, barometric pressure, humidity, solar radiation<br><u>Sedimentology</u>: Texture, compaction, composition, sediment volume<br><u>Biology</u>: Benthic invertebrates, fish, shorebirds/seabirds, dune/shrub/marsh vegetation, sea turtles |
| Terrestrial | <u>Land cover/land use</u>: Determine land-cover and land-use changes (in vegetation types, buildings, roads)<br><u>Biology</u>: Vegetative community assessment, fuel load<br><u>Soil</u>: Soil bulk density, pH, organic matter content |
| Atmospheric | <u>Meteorology (air)</u>: Wind speed, wind direction, relative humidity, temperature, solar radiation, precipitation<br><u>U.S. Environmental Protection Agency criteria pollutants</u>: Ozone and fine and coarse particulate matter (mass) |

[a] Sediment analysis, chemistry, and biology (including benthic microalgae) of the NRE benthic zone are characterized in Research Project AE-3.

Annually, each DCERP Module Team evaluates the spatial and temporal design of its monitoring program and assesses whether its existing program is collecting adequate data to address DCERP objectives and fill data needs. Most of the module teams indicated that the spatial and temporal design of their monitoring efforts are meeting their module's data needs; however, even those modules that have collected two full years of data concluded that more multi-annual data are needed to conduct assessments of variability and data trend analysis. Several of the Module Teams were able to modify the temporal and spatial extent of their monitoring networks to fill identified data gaps. However, some gaps in the monitoring program were identified, and the Module Team did not have adequate resources to improve the spatial extent of the monitoring network. For example, the Atmospheric Module believes the current monitoring program is missing critical information that would help place local airshed conditions on the Base within a broader regional context, and the Aquatic/Estuarine Module believes another monitoring station is needed on the New River to capture ecosystem processes occurring above the head of the tidal mixing zone not captured by the location of the existing monitoring station at Jacksonville.

## ES-3.2  DCERP Research Program

The research program was designed to increase the knowledge base and understanding of MCBCL–relevant ecosystem structure, function, and system responses to stressors and management actions and to lead to the development of adaptive management strategies. The overall research program that is presented in the DCERP Research Plan consists of 13 separate research projects (as shown in **Table ES-3**). All planned research projects were started during 2008, with the exception of Coastal Barrier Module Research Projects CB-1 and CB-2 and the field component of Research Project Air-1; all three of these research projects started on schedule in 2009.

**Table ES-3. Summary of the 13 DCERP Research Projects**

| Research Project Title | Senior Researcher; Project Duration |
|---|---|
| **AE-1:** Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom Dynamics, and Ecosystem Condition | Hans Paerl; 7/2007–11/2011 |

| Research Project Title | Senior Researcher; Project Duration |
|---|---|
| **AE-2:** Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens | Mike Piehler; 7/2007–11/2011 |
| **AE-3:** Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the NRE | Iris Anderson; 7/2007–11/2011 |
| **CW-1:** Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation | Jim Morris; 7/2007–11/2011 |
| **CW-2:** Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates | Mark Fonseca; 9/2007–11/2011 |
| **CW-3:** Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands | Craig Tobias; 7/2008–11/2011 |
| **CB-1:** Short-Term Barrier Evolution Related to Storms and Land Use | Jesse McNinch; 7/2009–11/2011 |
| **CB-2:** Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics | Tony Rodriguez; 7/2009–11/2011 |
| **CB-3:** Understanding the Top-Down and Bottom-Up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on Marine Corps Base Camp Lejeune | Sarah Karpanty and Jim Fraser; 7/2007–6/2011 |
| **T-1:** Effects of Different Midstory Restoration Management Options on Terrestrial Ecosystem Structure and Function | Norm Christensen; 1/2008–11/2011 |
| **T-2:** Effects of Habitat Management for Red-Cockaded Woodpeckers on Bird Communities | Jeff Walters; 1/2008–11/2011 |
| **Air-1:** Optimization of Prescribed Burning by Considering Mechanical Thinning as a Viable Land Management Option | Karsten Baumann; 7/2008[a]–11/2011 |
| **Air-2:** Nitrogen Deposition to Terrestrial and Aquatic Ecosystems | Wayne Robarge; 7/2007–11/2011 |

[a] The field component of Research Project Air-1 began in July 2009.

Note: AE = Aquatic/Estuarine Module; Air = Atmospheric Module; CB = Coastal Barrier Module; CW = Coastal Wetlands Module; T = Terrestrial Module.

## ES-3.3  Supplemental Activities

DCERP researchers can receive supplemental funding from SERDP if the activity (1) needs immediate funding to prevent a negative effect on DCERP, (2) is supported by a recommendation from the Technical Advisory Committee, (3) supports a new requirement based upon monitoring or research results, or (4) fills a data gap revealed by current work or enhances work that had already been funded. In 2009, SERDP approved six new activities (**Table ES-4**) that were pivotal to achieving DCERP objectives.

### Table ES-4. DCERP Activities That Received Additional Funding in 2009

| Title | Senior Researcher | Activity |
|---|---|---|
| Bathymetric Survey of the NRE and Major Tributary Mouths | Jesse McNinch | Programmatic |
| Advanced Circulation (ADCIRC) Model Implementation, Validation, and Tidal/Storm Surge Simulations for the NRE and Onslow Bay Region | Rick Luettich and Janelle Fleming | Monitoring |

| Title | Senior Researcher | Activity |
|---|---|---|
| Understanding the Role of Physical Disturbance in Regulation of the Benthic Microalgal Community and Its Role in Supplying Nitrogen for Ecosystem Production | Iris Anderson and Carolyn Currin | Research |
| Placing Coastal Barrier Monitoring in Context: Comparing Beach Faunal and Sediment Dynamics Between Onslow and Bear Islands | Stephen Fegley and Tony Rodriguez | Monitoring |
| Survival Estimates for Wilson's Plover (*Charadius wilsonia*), a Focal Shorebird Species in the Coastal Barrier Ecosystem, and an Initial Comparison of the MCBCL Wilson's Plover Population with Nearby Barrier Islands | Sarah Karpanty and James Fraser | Research |
| DIMS Enhancements to Support Data Integration, Analysis, and Synthesis and to Increase Usability and Functionality to Meet the Needs of All Data Users | Danette Boezio | Data management support |

## ES-4.  Aquatic/Estuarine Module Summary

Estuaries integrate inputs from terrestrial, freshwater, oceanic, and atmospheric systems, and the accurate assessment and management of estuaries necessitates consideration of their connections to, and interactions with, these other ecosystems. Estuaries also exist in regions where there are rapidly expanding and diversifying human activities. In the context of the MCBCL region, the Aquatic/Estuarine Module examines the tidal reach of the NRE from the freshwater head of the New River near Jacksonville, NC, to the tidal inlet at Onslow Bay. Understanding and sustaining the function of the NRE cannot occur without quantifying and distinguishing natural processes from human-influenced watershed- and airshed-based impacts upstream from the estuary. The overall monitoring and research program of the Aquatic/Estuarine Module is designed to understand the complementary physical, chemical, and biotic processes that determine water and habitat quality; differentiate natural and anthropogenic ecosystem stressors (past, present, and future) at local and regional scales; take account of extreme climatic events (i.e., hurricanes and droughts); and integrate results with the other DCERP modules. The benefits of the Aquatic/Estuarine Module monitoring and research program include providing information needed to preserve the sustainable use of the amphibious maneuver areas, including the NRE (Military Driver #1), and ensuring continued military training activities, while complying with the CWA (Military Driver #5), including state water quality criteria for chlorophyll *a* and bottom-water dissolved oxygen (DO) concentrations.

**Major accomplishments and benefits to the Base during 2009 include the following:**

- Water quality monitoring data collected at the U.S. Geological Survey (USGS) stream-gauging station in Jacksonville, NC, indicated that DO concentrations ranged from 0–17.5 milligrams per liter (mg/L) and that 23% of the DO concentrations at the station were <2 mg/L, indicating the presence of hypoxic conditions. Reductions in both nitrate and total nitrogen (TN) concentrations between the upstream station at Gum Branch and the downstream station at Jacksonville occurred; however, further investigation is needed to determine the cause of these reductions.

- The combined nitrogen (N) load from the 10 tributary creeks on the Base was estimated to be less than 25% of the total watershed loading of N to the NRE system, whereas contributions from the New River mainstem accounted for more than 75% of the N loading. These proportions may vary, depending on inter-annual hydrologic (storm versus drought years) variability.

- Several large phytoplankton blooms in mid-estuary to upper estuary locations exceeded the State of North Carolina's "acceptable" chlorophyll *a* concentration (40 µg/L) during the spring and summer seasons of 2008 and 2009 (**Figure ES-3**). Both the rate of primary productivity and the magnitude (biomass) of the blooms in 2009 tended to be larger in magnitude and more extensive spatially than those observed in 2008. These differences appear to be related to differences in

freshwater discharge and associated nutrient loading in contrasting years, as well as higher water temperatures. Blooms were spatio-temporally linked to periods of hypoxia in the upper estuary.

▪ Although tributary creek loadings of nutrients and total suspended solids (TSS) were generally higher from disturbed watersheds than from the paired reference watersheds across MCBCL, overall the loadings from the NRE tributary creeks were low, relative to other coastal systems. Water volume, not the concentration of nutrients or TSS, was the primary determinant of patterns in loading estimates.

▪ As part of the development of the Watershed Simulation Model, a Nitrogen Loading Model was applied to the sub-watersheds for the two USGS stream-gauging stations on the New River and the 10 tributary creek stations. This model was scaled up to predict loads to the entire NRE based on 2007–2009 DCERP monitoring data; these predictions will be refined with ongoing DCERP monitoring data.

▪ Benthic gross primary production (GPP) dominated or equaled the NRE system production by phytoplankton only at shallow depths; however, when GPP rates were scaled up to the mean NRE water depth, benthic GPP rivaled that of phytoplankton GPP only in the lower estuary during one month (May). This suggests that phytoplankton dominate GPP in the NRE. Early results also suggest that benthic GPP is controlled more by natural processes (i.e., watershed loading of color dissolved organic matter in the upper estuary and sediment resuspension in the lower estuary) than by man-made stressors (e.g., watershed loading of nutrients and sediments). Phytoplankton GPP is more nutrient-limited and thus responsive to changes in watershed nutrient loading.
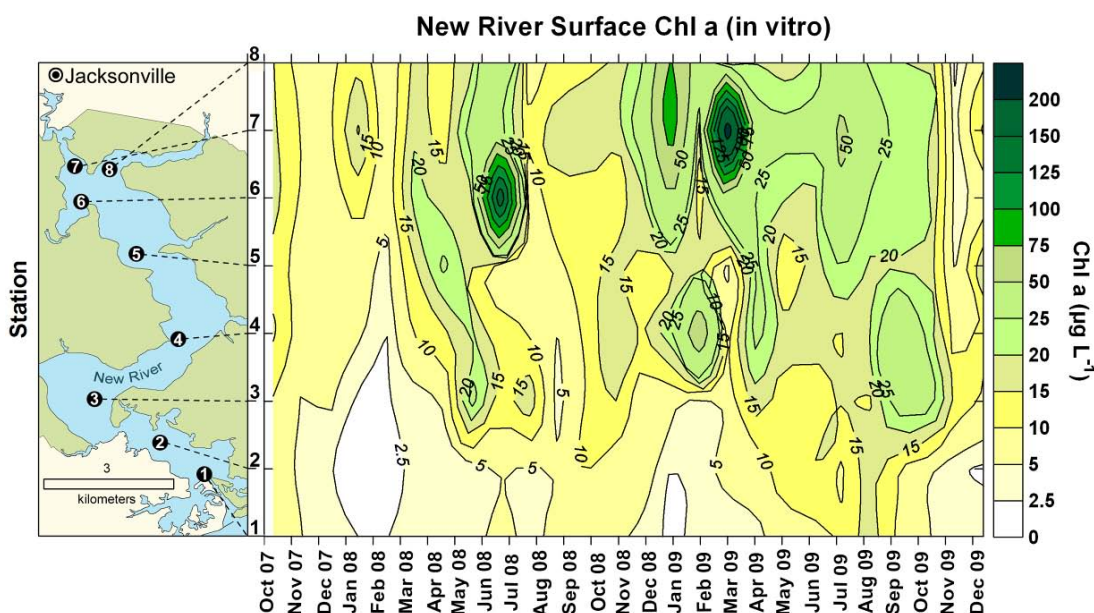


**Figure ES-3. Monthly surface water chlorophyll *a* concentrations for the NRE from the inlet to the river.**

## ES-5.  Coastal Wetlands Module Summary

The coastal wetlands under study at MCBCL include vegetated and non-vegetated intertidal habitats in salt and brackish waters, including adjacent mudflats, sandflats, and tidal creeks. The health of the coastal wetlands dictates their ability to serve as a trap for sediments and nutrients (and their transformation and exchange), which improves water quality in the NRE. In addition, marshes protect the Base's infrastructure by serving as a buffer against coastal storms and compensating for sea-level rise. Salt marshes also stabilize the structure of Onslow Island through the process of sediment accretion, and therefore are essential to barrier island sustainability. The overall monitoring and research program of the

Coastal Wetlands Module is designed to provide quantitative information about the condition and dynamics of coastal marshes at MCBCL and to forecast future changes in the condition of these coastal marshes due to anticipated increases in military training activities and sea-level rise. This module was designed to address three of the MCBCL military drivers: (1) to preserve the integrity of the amphibious maneuver areas in the NRE (Military Driver #1); (2) to ensure that MCBCL supports continued military training activities, while complying with the CWA (Military Driver #5); and (3) to ensure the viability of military training activities, while supporting mission-critical infrastructure development (Military Driver #7).

**Major accomplishments and benefits to the Base during this past year include the following:**

- Marshes located along the Intracoastal Waterway demonstrated significant variation in surface elevation change depending on baseline elevation. Despite elevation differences, above-ground marsh biomass did not differ significantly among these sites. Experimentally fertilized marshes continued to accrete sediments and increase their surface elevation at rates two to seven times greater than control marshes.

- All marshes along the NRE mainstem (i.e., Traps Bay, Pollocks Point, and French Creek) showed a significant increase in elevation in both 2008 and 2009. Sediment accretion rates were often much higher than elevation change rates, suggesting these fringing marshes are trapping sediments, but that significant sediment compaction also occurs.

- Shoreline location and habitat type were determined for the entire NRE by aerial photographic analysis and ground-truthed using field characterization. Field characterization was more accurate in determining both location and habitat type. Fifty-three percent of the NRE shoreline was identified as sediment bank, 21% as marsh, 19% as modified (i.e., hardened with man-made structures), 6% as swamp forest, and 1% as miscellaneous (e.g., bridges, docks).

- The rate of estuarine shoreline change was determined over three time periods: 1956–1989, 1956–2004, and 1989–2004. Over the 48-year period, the shoreline has receded an average of 12.9 meters (m), but the majority of shoreline eroded at a rate <0.5 meters per year (m/yr), which is comparable to erosion rates in the Neuse River Estuary, NC. Accretion was identified in more sheltered areas of tributaries, and higher erosion was identified in the main body of the NRE. Erosion rate information can inform Base managers of locations with increased vulnerability so that appropriate management actions can be taken to protect existing infrastructure and better plan for siting of future construction.

- New bathymetry data provided pivotal information for improving accuracy in the wave exposure hindcasts developed using



**Figure ES-4. Improved 2009 bathymetry for the NRE.**

National Oceanic and Atmospheric Administration's WEMo. There was much closer coherence of predicted and observed results with the newer high-quality bathymetry data (**Figures ES-4 and ES-5**). The improved models (developed with the new bathymetry data) will be delivered to the

Base for use by MCBCL emergency preparedness staff for planning Base response to simulated wave exposure scenarios forecast for selected weather and tidal conditions.

▪ The TN delivered via shallow groundwater to the marshes of the NRE within MCBCL lands is 5% of the tributary flux and only 0.1% of the N inputs from the New River. If the groundwater–marsh N flux estimate is extrapolated to the marshes along the entire NRE shoreline, then the input of N via direct groundwater discharge is only 1.3% of the N input from the New River mainstem. The form of TN delivered by these marshes is ammonium-rich, relative to the TN loads from the tributaries and mainstem New River, which is predominantly nitrate.
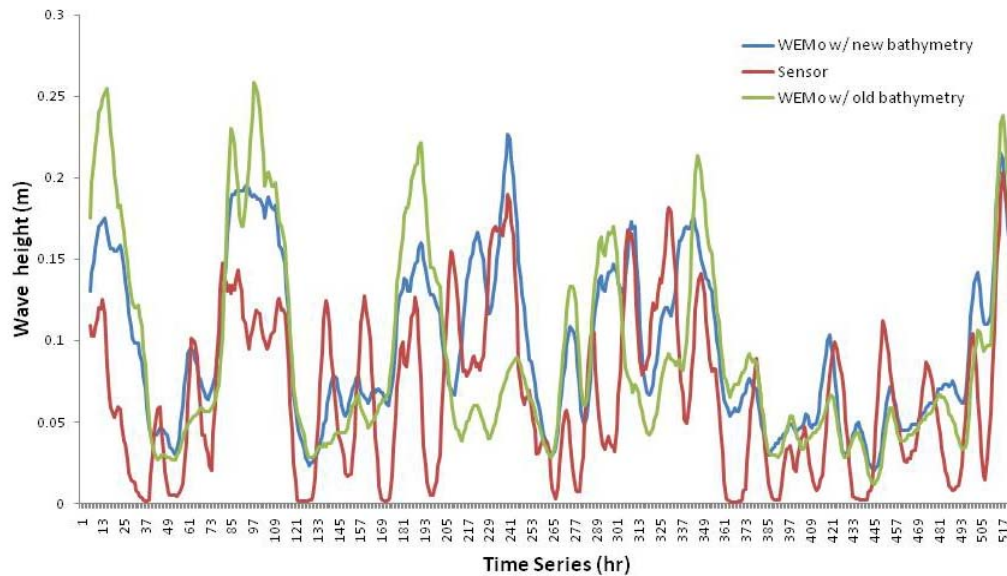


**Figure ES-5. Predicted and observed wave energy based on old versus new, improved bathymetry.**
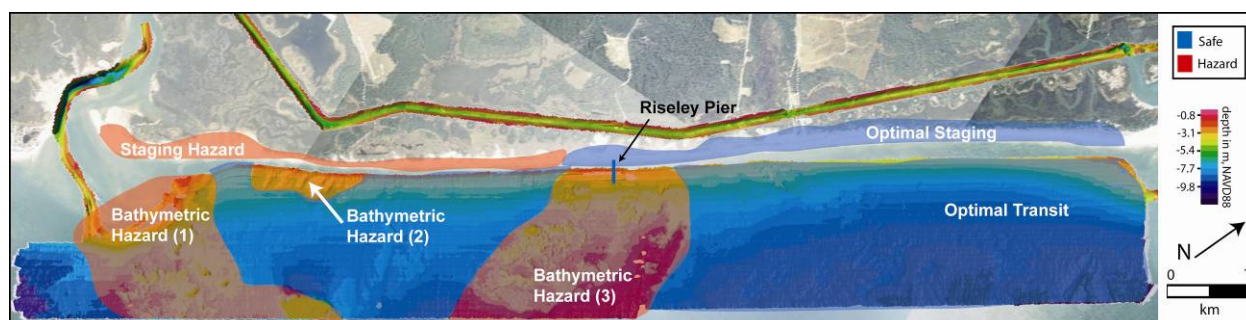
## ES-6. Coastal Barrier Module Summary

The Coastal Barrier Module study area includes Onslow Island, from the New River Inlet to Browns Inlet, and the newly added stations on Bear Island that are acting as reference sites (i.e., relatively free from human disturbance). This ecosystem encompasses the shallow subtidal and intertidal shore face, the tidal inlet, the backshore beach, dunes, shrub zone, the incipient maritime forest, and washover sand flat habitats. These habitats are defined by intrinsic ecological processes, but are linked by sediment transport, nutrient exchange, and biological uses, each of which undergoes substantial changes over multiple time scales. Onslow Island is a critical part of the Base's amphibious assault training program and, as a result, warrants management strategies that will enable continued training use of the beach, while managing it as a sustainable ecosystem. Understanding erosion-rate variability due to various natural and human activities will help improve management of the coastal barrier and preserve the integrity of the amphibious maneuver areas, including Onslow Bay (Military Driver #1). In addition, the Coastal Barrier Module's monitoring and research programs will help the Base comply with the ESA (Military Driver #4) by understanding the habitat quality needed to sustain sea turtle and shorebird use of the island.

**Major accomplishments and benefits to the Base during this past year include the following:**

▪ Comparisons between long-term trends in shoreline behavior and the volume of sediment comprising the beach suggest that a simple linear relationship does not exist between the two. The volume of sediment encompassing a given stretch of beach does not predict shoreline erosion,

which suggests that other factors, rather than beach sediment volume alone, exert a measurable influence on the long-term behavior of the shoreline. We are investigating how other environmental metrics (e.g., nearshore bathymetry, nearshore sediment volume, influence of nearshore and surf-zone bathymetry on storm-surge and associated erosion) influence the long-term stability of Onslow Beach.

▪ Using data from Onslow Beach, three easily measurable metrics were identified to provide critical landing and staging information for military commanders working in hazardous coastal zones. These metrics included (1) nearshore bathymetric gradients, (2) nearshore sediment volume, and (3) changes in shoreline and vegetation line position. These data were coupled with a quantitative understanding of the relevant coastal processes and allowed for an assessment of potential nearshore bathymetric hazards and realistic predictions of short-term shoreline stability, and thus suitability for the temporary staging of military equipment (**Figure ES-6**).



**Figure ES-6. A coastal hazards map for MCBCL. Transit and staging hazards are shaded in red, and non-hazardous regions are shaded in blue.**

▪ In 2009, the Coastal Barrier Module completed digitizing hard-copy files of sea turtle nesting data from 30 years of archived historic records that were made available for analysis by MCBCL.

Analysis of these data files confirmed the effectiveness of MCBCL ESA management activities to move nests from military training areas to non-training areas, since relocated nests have an average estimated survival rate equal to or higher than those of undisturbed nests laid in non-training areas.

▪ Ghost crab burrows occurred in greater numbers towards both the southern, overwash area (Focus Sites 1 and 2) and the northern end of the island (Focus Sites 6 and 7). Significantly lower abundances of ghost crab burrows were found in the military training portion of the beach, which may indicate broader environmental impacts of training activities; however, these results require further investigation (**Figure ES-7**).

▪ Predator populations were monitored in the recreational and southern overwash areas of Onslow Island to assist MCBCL staff in fine tuning the Base's predator management program to benefit shorebird and sea turtle productivity. Researchers are working with
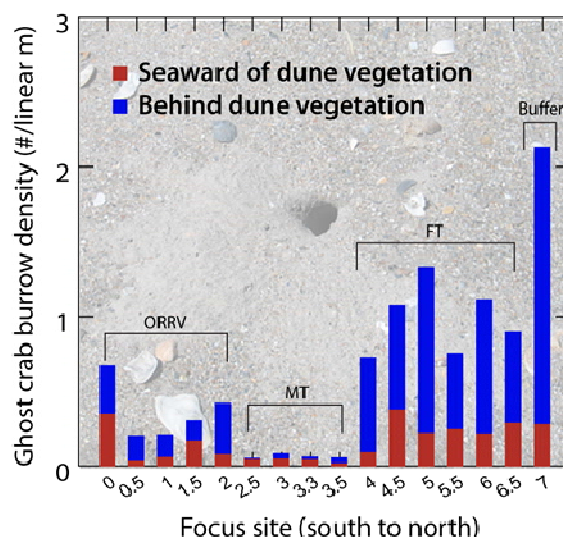


**Figure ES-7. Ghost crabs are an important link in the food chain of Onslow Island. Results indicate lower population abundance in the military training zone than elsewhere on the island. Note: FT = foot traffic; MT = military training; ORRV = off-road recreational vehicles.**

> Base staff to evaluate highly traveled predator trails in the southern overwash area to determine where traps should be set for the nest-egg predators targeted for trapping—opossums *(Didelphis virginiana)* and raccoons *(Procyon lotor)*.

▪ Researchers analyzed data on Wilson's plover behavioral and demographic responses to an Atlantic Coast sea level anomaly in 2009; these data are directly relevant to assessing impacts of sea-level rise related to climate change on this and other similar breeding shorebird species. This is a unique data set resulting from a natural event that researchers were able to witness and study effectively.

## ES-7. Terrestrial Module Summary

The terrestrial ecosystem at MCBCL encompasses the gradient of vegetation from the salt marsh at the estuary margin, through the brackish and freshwater marsh, to the longleaf pine (*Pinus palustris*) savannas and pocosins (shrub bog) that dominate MCBCL's terrestrial environments. Variation in the biota and ecosystem processes along these gradients is driven by a variation in hydrology, soils, and fire behavior. The terrestrial ecosystems of MCBCL, particularly the longleaf pine savannas, are focal locations for many military training activities central to the Base's mission, and these activities have important impacts on the ecosystems along this gradient. The main objective of the Terrestrial Module is to provide a better understanding of the functioning of the entire terrestrial ecosystem to enable MCBCL managers to better integrate military training with natural resources management objectives, such as forest sustainability, habitat restoration, and endangered species recovery. The monitoring and research program of the Terrestrial Module is designed to provide baseline information on the land-use/land-cover changes that have occurred at MCBCL over the past 25 years and to monitor future changes throughout the duration of the DCERP project. Other objectives are to develop and implement protocols for the efficient monitoring of terrestrial ecosystems and to conduct focused studies on existing loblolly pine (*Pinus taeda*) habitat that are being restored to longleaf pine habitat by MCBCL natural resources managers to support recovery of the red-cockaded woodpecker (RCW) (*Picoides borealis*) and examine the effects of RCW management on the avian community diversity as a whole. The results from these programs can be applied by MCBCL staff to enhance future uses of MCBCL ranges and training areas (Military Driver #3) and to ensure that MCBCL supports required military training activities, while complying with the ESA (Military Driver #4).

**Major accomplishments and benefits to the Base during the past year include the following:**

▪ A Landsat Thematic Mapper 5 time series was processed for MCBCL to conduct a Greenness Change Analysis. In addition to identifying areas with varying gains and losses (measured as greenness) of vegetation due to land management practices, it was calculated that between 1984 and 2009, 3,900 hectare (ha) or 7.7% of MCBCL's total lands (57,824 ha) experienced a permanent loss or removal of vegetation. For the most recent change analysis period (2007–2009), 1.6% of land surface (791 ha) of MCBCL lands experienced significant loss or removal of vegetation in concentrated areas, likely representing new construction related to the Marine Corps Grow the Force Campaign.

▪ Vegetation sampling by Terrestrial Module researchers was completed on 91 monitoring plots, representing the full range of site conditions across MCBCL, including 25 plots located on Onslow Island (coinciding with Coastal Barrier Module sampling stations). Across all monitoring plots, more than 300 plant taxa were identified, with an average of 45.5 species in each 0.1-ha plot (range = 17–90 species/0.1 ha).

▪ Bird community composition during 2009 was sampled at 148 bird census point locations across MCBCL. Four rounds of census point counts produced 7,500 individual records, representing a diverse community of 95 different bird species.

▪ Three rounds of nest searching for cavity-nesting birds, conducted on thirty 9-ha plots, detected 124 nests, representing 11 avian species. The majority of cavity nests (58%) occurred in pine snags, followed by 31% in living pine trees, and 11% in hardwood snags (**Figure ES-8**). Researchers were able to quantify the preferred excavating substrates selected by primary cavity excavating species and identify interrelationships of the cavities use by primary cavity nesters and cavities used by secondary cavity nesters, which may have implications for future management of RCW and other avian species.
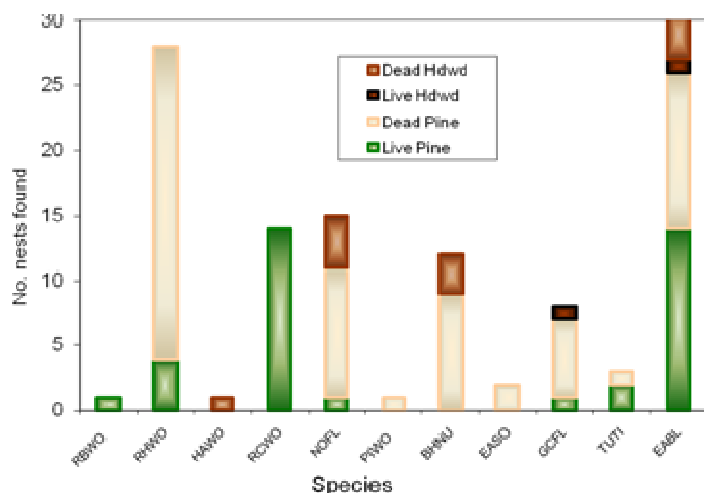


**Figure ES-8. Nests found during the 2009 field season by bird species with nesting substrate.**

Note: Hdwd = hardwood tree

## ES-8. Atmospheric Module Summary

The input of nutrients and potential pollutants via atmospheric deposition interacts with key terrestrial and aquatic ecological processes occurring at MCBCL. Inputs of these nutrients and pollutants can come from local (on Base) or regional (off Base) airshed sources constrained by predominant wind patterns.

The Atmospheric Module's monitoring and research programs were designed to describe and improve the understanding of critical pollutant transport and advection processes that are subject to complex land–sea breeze circulation patterns and more regional synoptic forces. This improved understanding will be gained through identification of sources internal and external to MCBCL and their respective range of impacts to ensure Base compliance with the CAA. In addition, the Atmospheric Module is collecting data to estimate the total atmospheric nutrient loading (to open-water surfaces of the NRE and to vegetation surfaces of MCBCL lands), which is critical information needed for developing an N budget for the NRE. This atmospheric loading estimate will, in part, address the MCBCL military driver to ensure that the Base supports continued military training activities, while complying with the CWA. (Military Driver #5)

**Major accomplishments and benefits to the Base during 2009 include the following:**

▪ Among all sites in the study region, the Onslow Beach site received the highest average ozone concentrations from the south and southeast directions, pointing to effects from photochemical production of ozone under maritime conditions and transport to the Base lands with the sea breeze. Overall, however, there was a statewide trend in 2009 that showed the lowest ozone concentrations in North Carolina Department of Environment and Natural Resources records. Future monitoring will determine whether this trend continues.

▪ In contrast to ozone, $PM_{2.5}$ (particulate matter with a diameter less than or equal to 2.5 microns [μm]) daily and annual design values (measured 3-year average concentrations) increase with increasing distance from the ocean, correlating with decreasing amounts of rainfall, which is the most effective sink for atmospheric $PM_{2.5}$.

▪ $PM_{fine}$ (≤2.5 μm) and $PM_{coarse}$ (2.5 μm–10 μm) concentrations are distinctly different locally and on short time scales between the Onslow Beach site and the site 20-kilometers (km) inland from the beach in Greater Sandy Run Area. These differences in concentrations are likely due to

impacts from distinct local source activities such as military training; however, prescribed burning and/or wildfire sources cannot be entirely excluded (**Figure ES-9**).

▪ Preliminary analysis of throughfall samples collected under a predominately longleaf pine canopy suggests that organic nitrogen is the dominant form of N reaching the forest floor (via dry deposition), and inorganic nitrate-nitrogen constitutes 30% of the N loading. Based on 3 months of data, the N loadings from atmospheric deposition are relatively modest. On a mass basis, total dissolved organic carbon represented the largest input to the forest floor, followed by chloride, sulfate, and sodium.



**Figure ES-9. Smoke plume from a prescribed burn at MCBCL.**
(Photo credit: Bob Yokelson)

## ES-9. Data and Information Management System

To support the data management needs of DCERP and the complex and voluminous environmental data being collected and used for the program, it is crucial to make research results, monitoring information, and other data accessible to the DCERP Team. The DCERP DIMS is a database-driven Internet system that provides a means to access and manage the DCERP data collections and provides useful and scientifically sound data and information in a framework to support ecosystem-based management tools. To accomplish these tasks, the DCERP DIMS consists of the MARDIS, the Document Database, public and Collaborative Web sites, and a Geographic Information Systems Mapping Tool for MARDIS.

**Major accomplishments and benefits to the Base during 2009 include the following:**

▪ The DCERP Team finalized monitoring and research data sets for uploading to ensure that all data sets are archived and available in MARDIS within 6 months for monitoring data and within 2 years for research data from the date collected. This task included the completion of customized tools to assist the DCERP researchers with transposing their monitoring and research data into the master data templates and the format necessary for uploading data into MARDIS.

▪ The Data Management Module staff developed a Data Policy for various data users that was approved by SERDP, MCBCL, and the DCERP researchers. This policy delineates clear responsibilities for all data users and the conditions for accessibility to monitoring and research data.

▪ MARDIS contains more than 14-million records of monitoring and research data that are available to the DCERP Team. Due to large file sizes, processes were implemented to download data containing more than 10,000 data records in a timely manner.

▪ The Data Management Module staff added an interactive station map interface to the MARDIS Web site, which allows users to view station sites by ecosystem module and to interactively click on the station sites and view detailed station information, including collected parameters, along with a small representative sample of the data collected at that station.

▪ The Data Management Module staff created a dataset report to display the current collection of data sets available in MARDIS, including available date ranges for each data set. In addition, to assist users in identifying whether new data have been added or modified since their original uploading to MARDIS, a data revision log was created to show the most recently uploaded data and the date of the upload.

## ES-10.  Summary

Implementation Year 2 of DCERP has resulted in significant findings regarding ecosystem function and structure in areas such as estuarine and tributary water quality, air quality, barrier island morphology, and accretion–erosion dynamics in coastal wetlands. Significant findings and progress throughout 2009 were reported at the Technical Advisory Committee meeting, which included MCBCL and SERDP staff. This meeting provided review and scientific evaluation of each research project's achievements and direction and its relevance to Base management needs. In addition, DCERP researchers have regularly briefed MCBCL staff on monitoring and research efforts during several technical meetings and invited seminars to keep the Base staff informed on DCERP activities and obtain their feedback to better understand Base management needs. The presentation of findings at various scientific forums and conferences has informed the wider scientific community about DCERP's ongoing research efforts.

## ES-11.  Next Steps

In the coming year (2010), many of the DCERP Module Team members will incorporate the new high-resolution bathymetry data into their cross-module modeling efforts. These models will provide better information on estuarine circulation patterns, flushing rates, and exchange patterns; will refine the Nitrogen Loading Model component of the Watershed Simulation Model; and provide revised predictions of tidal and storm driven water levels (via WEMo) throughout the estuary to assist with marsh elevation and shoreline erosion studies. The Aquatic/Estuarine Module will continue analyses of phytoplankton and benthic microalgal processes on the NRE and loadings from the tributary creeks and the New River. The Coastal Wetlands Module will finalize results of the impact of Landing Craft Air Cushion use in the lower NRE marshes and install an additional marsh organ to help reduce variability in research studies. The Coastal Barrier Module will continue to monitor physical and biological parameters (fish and invertebrates) on Bear Island (reference site) and on Onslow Beach. The Coastal Barrier Module's Research Project CB-3 will determine the survival of Wilson's plovers by sampling on Onslow Beach and on two adjacent islands (i.e., North Topsail Beach and Bear Island). The Terrestrial Module will determine the vegetative diversity across MCBCL and analyze the impact of various forest management practices on vegetation structure. The Terrestrial Module's Research Project T-2 will continue studies of RCW habitat quality and avian community studies. An assessment of insect diversity in the Research Project T-1 research plots and their relationship as food for other avian species will also begin. In addition, the Terrestrial Module will continue to look at land-use and land-cover change patterns on the Base. The Atmospheric Module's Research Project Air-1 will evaluate particulate and gaseous emissions from both flaming and smoldering phases of prescribed burns on plots managed with mechanical fuel treatments compared to untreated sites. The co-located results from Research Projects T-1 and Air-1 will assist Base managers in evaluating the effects of forest management practices on the prescribed burning emissions and restoration targets. The Data Management Module will complete implementation of a Document Database, continue to enhance the user interface of MARDIS and, provide support for uploading monitoring and research data to MARDIS.